Thermal Striping

David J.Torres, Rick M. Rauenzahn, Manjit S. Sahota, T-3

One facet of our Global Nuclear Energy Partnership (GNEP) activity has focused on modeling an experimental problem in which two liquid sodium jets at different temperatures impinge on a steel plate [1]. Thermal striping refers to the temperature fluctuations that are observed at the interface between two non-isothermal jets. This experiment is designed to reproduce a similar condition in the upper plenum of a liquid metal cooled fast breeder reactor (LMFBR). Heat is readily transferred to the steel, subjecting it to a repetitive cycle of temperature fluctuations that could potentially lead to fatigue and crack initiation.

We model the problem with the Computational Hydrodynamics for Advanced Design (CHAD) code, which is a parallel, finite-volume code capable of accommodating unstructured grids. Two inflow nozzles (one at 721 K and the other at 574 K) are placed 38 mm from a steel plate to match the experiment. The experiment is designed to be 2D by using nozzles with a rectangular cross section, thus we perform our calculations in a 2D grid. Figure 1 shows the dimensions of the computational domain. Each nozzle injects liquid sodium at 3.36 m/s into the computation. Two outflow boundaries at the upper left and upper right allow the sodium to exit. The steel is modeled using an isothermal equation of state, and the sodium is modeled with a Mie-Gruneisen equation of state. Calculations are run for an initial period of time to allow for the flow to develop.

Figure 2 shows a snapshot of the temperature just below the steel plate where the grid resolution is 1.4 mm in the horizontal direction and 0.475 mm in the vertical direction. The steel plate is physically above the region outlined by the box. The hot (red) sodium jet and the cooler (blue) sodium jet become unstable and interact to form eddies that travel outward from the center of the steel plate. One should note that sodium has a low kinematic viscosity so the Reynolds number is high (∼50,000).

Figure 3 shows a time history of the temperature of sodium and that of steel at fixed points at the finest resolution (1.4 mm by 0.475 mm). The distances displayed in the legend are measured from the surface of the steel plate facing the sodium jets. Thus (-82 mm, -2 mm) is -82 mm to the left of the horizontal middle of the steel surface and 2 mm down from the steel surface. The fluctuation is not a regular oscillation. The oscillation in the experiment is also not a regular periodic oscillation. The amplitude (and to some extent the frequency) of the oscillation in Fig. 3 depends on the location of the point sampled and ranges from approximately 3 K to 10 K at the surface of the steel to roughly 10 K to 45 K in the sodium. The amplitude quoted in the experiment is 20 K in the steel and 40 K in the sodium.

Fig. 4 shows the temperature oscillation in the sodium at three different grid resolutions at (-82 mm, -2 mm). The temperature in the lowest grid resolution (5.625 mm in the horizontal direction and 1.9 mm in the vertical direction) has been shifted down 40 K so that all three time-history plots at different resolutions could be compared. The frequency of oscillation at the lowest grid resolution can be identified and is 31 Hz. The behavior at the finer grid resolutions is more erratic,

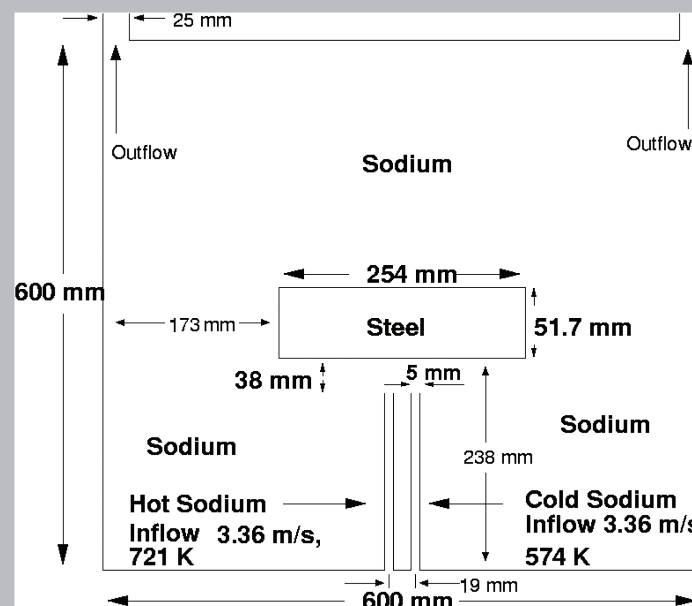

Fig. 1. Computational dimensions.

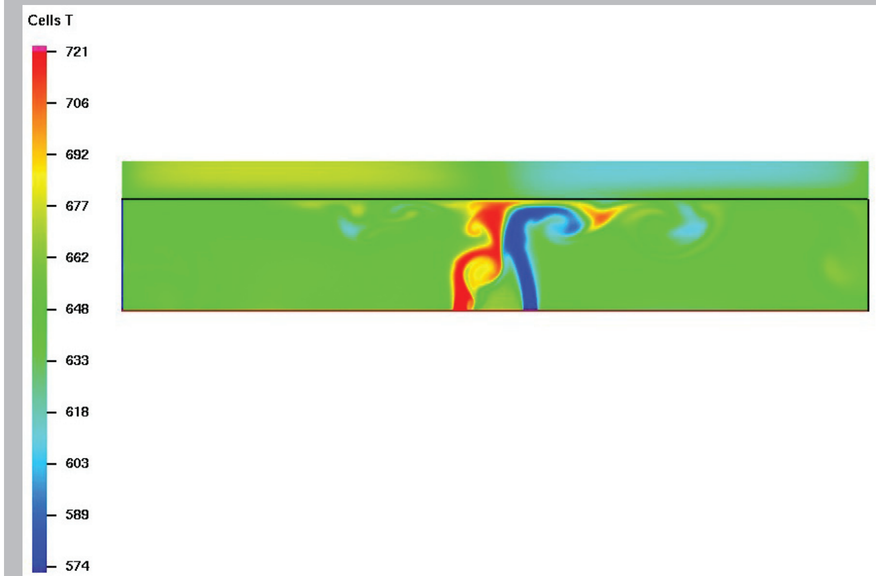

Fig. 2. Sodium and steel temperature.

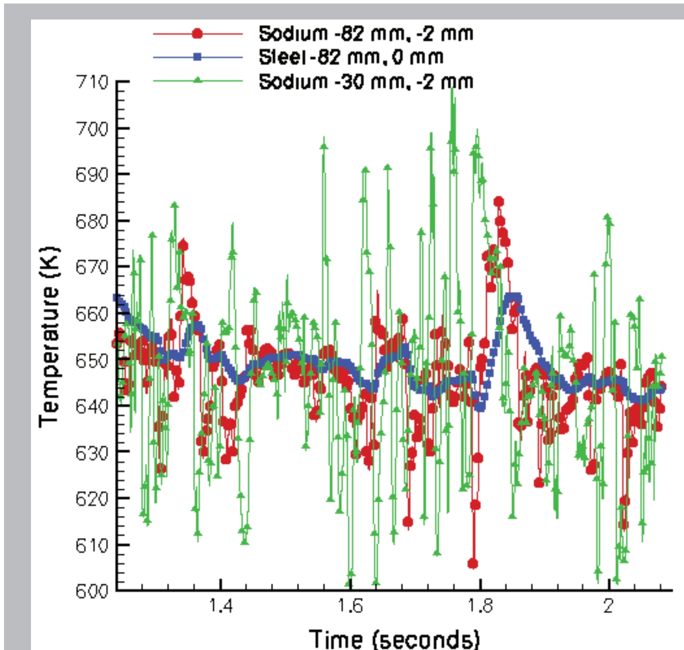

Fig. 3. Temperature history in sodium and steel.

but still periodic in nature. The frequency quoted in the experiment is 14 Hz. However, if one counts the number of peaks in the experimental temperature history plot, the experimental frequency could be estimated to be between 23 and 28 Hz.

With CHAD, we have modeled an experiment relevant to reactors and demonstrated that the code can qualitatively reproduce the flow seen within the experiment and thus shed light on the complex physics encountered within reactors.

For further information contact David J. Torres at dtorres@lanl.gov.

[1] K. Velusamy, et al., draft paper, *CFD Studies in the Prediction of Thermal Striping in an LMFBR*.

Funding Acknowledgments
- Department of Energy, Global Nuclear Energy Partnership

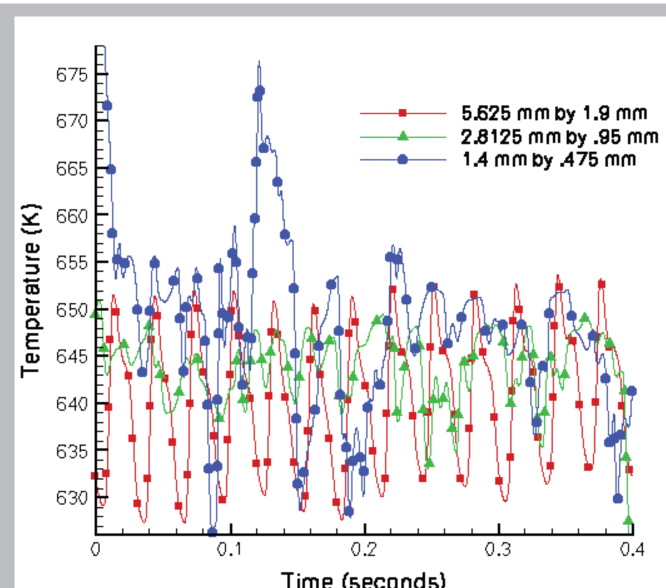

Fig. 4. Temperature history in sodium at three different grid resolutions.